UGV Interoperability Profile (IOP)
Capabilities Plan
For
Version 0

Robotic Systems, Joint Project Office (RS JPO)
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14. ABSTRACT
UGV Interoperability Profile (IOP) version 0 (V0) has been defined by the RS JPO to serve as a commonality baseline that can be successively built upon by subsequent versions of the IOP. This commonality baseline is largely interpreted as ?common? with the robotic capabilities currently employed in fielded operations today as well as those capabilities planned to be acquired via robotic program initiatives over the next few years. This document provides general guidance and clarification with respect to the set of interoperability capabilities to be covered within the V0 UGV IOP. In general, this IOP Capability Plan will be a ?living? document that will address specific requirements and capabilities applicable to planned and emerging robotic systems and will; in coordination with the RS JPO, User Community, and UGV IOP Interoperability IPT align those capabilities to future IOP Versions that will in turn be aligned with robotic program acquisition initiatives.

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Table of Contents

1 Scope

1.1 Overview

UGV Interoperability Profile (IOP) version 0 (V0) has been defined by the RS JPO to serve as a commonality baseline that can be successively built upon by subsequent versions of the IOP. This commonality baseline is largely interpreted as “common” with the robotic capabilities currently employed in fielded operations today as well as those capabilities planned to be acquired via robotic program initiatives over the next few years. This document provides general guidance and clarification with respect to the set of interoperability capabilities to be covered within the V0 UGV IOP.

In general, this IOP Capability Plan will be a “living” document that will address specific requirements and capabilities applicable to planned and emerging robotic systems and will; in coordination with the RS JPO, User Community, and UGV IOP Interoperability IPT align those capabilities to future IOP Versions that will in turn be aligned with robotic program acquisition initiatives.

1.2 Applicability

This document was developed as a means to provide details associated with V0 capabilities by providing capability intent along with associated limitations and constraints as applicable to the V0 development effort. This document serves to provide guidance to the WIPT organizations participating in the V0 development in identifying and defining systems and controller inter/intra-interoperability. This document does not define how things are to be done (implementation of requirements to interoperability standards or messages). In addition, while this document will retain a level of traceability to the V0 IOPs, that traceability will not necessarily be a one to one correlation between a defined capability and the manner in which it may be specified.

2 Capabilities Definition Process

The simple intent of the capabilities definition process is to identify, specify, and define key robotic capabilities and assign them in an aligned sequential fashion to IOP version releases with respect to a determined acquisition need date. Initially this is very difficult to do given the fact that V0 capabilities span a set of capabilities that have already been fielded as well as a set of capabilities that will be fielded in the near future. At some point in time, this paradigm will shift and the capabilities identified in this plan will be able to be defined in advance of a projected acquisition initiatives allowing for the ability to define interoperability mechanisms that can then be employed as part of the acquisition cycle.

With respect to V0, capabilities were identified by two different methods and then vetted within the RS JPO and the User community. The first method involved an analysis of currently fielded systems and the identification of common capabilities in accordance with the IOP Capabilities taxonomy defined within the Overarching IOP. Current systems that were analyzed included the PackBot, Talon, and MARCbot platforms (some in varying configurations). The second method included analyzing requirements

specifications and identifying capabilities for systems either in procurement or in development within the User community. Systems that fell into this category included the SUGV and the SMET.

In successive versions, this capabilities plan will be more directly tied to artifacts developed within the program acquisition and User community, such as the Unmanned Systems Initial Capabilities Document, the Robotics Roadmap and the UGV Campaign Plan. As many of these artifacts were being developed at the same time as this version of the campaign plan, it was not practicable to achieve the same level of synergy as that planned for future versions.

The fact that V0 draws its capabilities from an existing base, comprised of platforms developed among a set of disparate vendors as well as a set of capabilities defined and addressed within the JAUS community, the complexity and intent is less vague than capabilities that were purely developmental in nature. This fact should prove helpful with respect to interpretation and in general, simplify the effort associated with interpreting and defining the V0 capabilities. As the process evolves and moves into new capabilities that are not part of today's robotic fleet the gaps will increase, requiring more reliance and guidance.

3 Capabilities

The capabilities defined below are presented in accordance with the IOP Composability taxonomy defined within the Overarching IOP. It should be noted that even though these capabilities are specified as "common" by nature of the V0 definition, it is understood that not all capabilities will be available within every robotic system and in some cases, there may be some variation in how the capability is defined/provided. The goal of the IOP is to define an interoperable manner to address these capabilities across robotic systems, i.e. - to address the manner in which systems may choose to implement or not implement various capabilities (e.g., through interoperability attributes and/or metadata definition). In addition, the goal is to also providing ways for external systems; e.g., controllers, to know what capabilities are available from/configured for a particular platform in compliance with the IOP. This is an overriding requirement to be addressed consistently throughout the IOP, the manner of which is not explicitly defined as a capability within this plan.

In addition, the definitions below serve as guidelines and are inclusive or exact. The definitions are specified to relay intent with the understanding that WIPTs may need to extend or modify the definitions. The limitations and constraints provide somewhat loose boundaries, but in general are specified to limit unnecessary effort to over specify capabilities with respect to their interoperability implementation.

3.1 Platform/Vehicle

The platform/vehicle capabilities are those capabilities inherent to the robotic platform independent of mission equipment payloads. In general, these capabilities define interoperability requirements relating to the state of the robotic system and provide for control/movement of the robotic system. The platform/vehicle capabilities are subset

into basic and advanced capabilities where basic refers to capabilities applicable to most platforms and advanced refers to capabilities that provide enhanced reporting and control common or specific to more advanced robotic systems. For version zero (V0), only basic capabilities are addressed. The manner in which advanced capabilities are further subset and defined will be addressed in future versions of this document.

3.1.1 Electrical, Mechanical, and Power

Description: These capabilities provide for the definition of standards to promote interoperability of platform/vehicle subsystems and payloads.

Limitations and Constraints: The intent of this capability with respect to version 0 is to accommodate currently fielded systems at a minimum and to start to define interoperability attributes/mechanisms to profile requirements and standards in these areas to accommodate the scalability of robotic platforms. In general, the platforms for consideration fall into the following classes: Soldier Transportable, Vehicle Transportable, and Self Transportable. Physical standards for micro and nano robotic platforms are not a high priority (e.g., nanobots and throw bots).

Other Guidance: To the degree possible, standardization of power, connectors, and mechanical mounting should be considered, with power and connectors being the highest priority.

3.1.2 Basic platform

Basic platform defines capabilities associated with the physical infrastructure that contains and supports various robotic system subsystems. The capability requirements in the basic platform are the most basic requirements for a robotic system to function.

3.1.2.1 Battery Status

Description: Provides the status of the battery(ies) utilized to power the robotic platform and the OCU. The intent is to provide a current charge level of the battery.

Limitations and Constraints: The intent is to provide just the charge level of the battery, allowing the user to make informed decisions about mission capability. In subsequent versions, additional information may be added (e.g., battery chemistry, loads, temperature, critical levels). The WIPTs may add additional information as deemed important for basic functionality, but advanced functions should not be pursued at this time.

Other Guidance: JAUS messages may need to be recommended. Physical connections will need to be considered, such as U.S. Army DWG# SC-C-179495 (for the BB2590). Power standards may need to be created for the various vehicle classes. Low power warnings may also need to be discussed. The WIPTS will need to determine these power standers and limits.

3.1.2.2 Usage

Description: Provides the ability to record or track the usage associated with the robotic platform. The usage will likely be stated as a distance traveled and hours of operation of the system (one set for the platform, and one set for the OCU). Much like an odometer, this should not be reset, however a single use “trip meter” may be included if it is deemed necessary. This should not be confused with “usage” as defined with respect to JAUS.

Limitations and Constraints: Basic functionality in IOP V0 should allow for usage times or distances to be recorded / reported. There is no expectation that the basic data will be used for advanced features, such as prognostics at this time.

Other Guidance: JAUS messages may need to be recommended.

3.1.2.3 Engine Data

Description: Provides information required for the user to operate the robotic platform with a basic engine as the energy source. This could include information such as fuel levels, engine RPM, Oil Pressure, and Oil Temperature as well as other parameters deemed necessary by the WIPT members.

Limitations and Constraints: The intent is to provide basic information for a basic engine. As new energy sources and advanced engines (e.g., compressed natural gas, hydrogen, sterling engine) are introduced and requested, they can be added to later versions of the IOP.

Other Guidance: JAUS messages may need to be recommended. Messages required for driving vehicles will be captured under the Basic Mobility Capability.

3.1.2.4 Platform Mode

Description: Provides a definition of the states associated with the robotic platform and may be utilized as a means to specify available functionality associated with the platform itself or with integrated mission packages/payloads.

Platform mode describes the current operational state of the robotic system. This may include startup, shutdown, standby, ready, in use/busy, and reset. It may also include modes as determined by the WIPT membership. The platform mode is different than the drive mode, in that all drive modes could go into a startup or standby mode, or be reset.

Limitations and Constraints: The most basic set of platform modes should map to most/all robotic systems even if they do not specifically report a platform status (e.g., startup, operational, shutdown). Additional modes such as maintenance, standby, timed shutdown, anti-tamper, render useless are envisioned for future robotic systems, but are not at this time considered part of the basic capability.

Other Guidance: JAUS messages may need to be recommended. WIPTs may want to consider, but not necessarily define, future state/mode requirements when deriving this

capability as a means of defining a platform mode element that can be scaled to meet future capability requirements.

3.1.2.5 Position/Attitude

Description: Provides a standard mechanism to report the position/attitude of the robotic platform. For the basic platform, this is envisioned to be a geo-referenced location on the earth; a heading (referenced from the front center of the vehicle); and an indication of the pitch and roll. It is recommended that the system report based on a local reference frame, as well as a global reference frame, such as the WGS84 standard. The WIPTs may determine other standards for position and attitude.

Limitations and Constraints: The location and attitude (heading, pitch, roll, etc…) include only a simple data point. Later versions can include more advanced information as required. This capability should be defined to allow for systems to partially conform in accordance with their ability (e.g., report location and heading only in the absence of an internal navigation package).

Other Guidance: JAUS messages may need to be recommended. Additional standards will need to be identified to accurately describe the data point.

3.1.2.6 Subsystem Configuration

Description: Provides the ability to identify and report the presence and type of payloads available to the robotic platform. In addition, this capability provides a high level interface to enable/disable integrated subsystems. This will be related to discovery services.

Limitations and Constraints: This is a high level capability that provides information to the operator regarding the system/subsystem level configuration of the robotic platforms and its integrated payloads. Examples include statements identifying the ability to move, use cameras, or the type of payloads. The level to which the robotic system reports this information will be largely a function of the program/system design, but conceptually this capability will scale to support more advanced capabilities associated with future revisions (e.g., calibration, BIT/FIT, power management).

Other Guidance: JAUS messages may need to be recommended. Physical connections will be captured under the payload and overarching sections.

3.1.2.7 Subsystem Health

Description: Provides a high level health status (Ok, Failed, Degraded) associated with the platform subsystems. This capability is closely associated with the Subsystem Configuration with respect to the subsystem reporting and tree structure.

Limitations and Constraints: The health monitoring only provides basic information and is not intended to provide in depth diagnosis/fault reporting. Advanced messages describing the exact failure, nature of the failure or prognostics may be added in later

versions, and could be included in a system's specification outside of the interoperability profile.

Other Guidance: JAUS messages may need to be recommended.

3.1.2.8 Pose/Articulation

Description: Specifies a set of pre-programmed poses that a robotic platform may utilize. Not all systems will utilize all poses, but a base set of poses can be developed for use with an interoperable controller. Examples could include "stow", "deploy", and "drive".

Limitations and Constraints: Some systems may have many poses, while others may have few or no poses. For this capability only basic poses should be considered. In subsequent versions, the ability of the system to send possible pose descriptions to the operator may be considered. This capability may be limited by the payloads placed on the system, and may be limited in functionality for IOP V0. The WIPT and user community will decide on these poses.

Other Guidance: JAUS messages may need to be recommended.

3.1.2.9 E-Stop, or Emergency Stop

Description: The robotic system should be able to receive an emergency stop message which places the robot into a safe state (this state will likely need to be considered in the definition of the platform mode).

Limitations and Constraints: The E-stop should be able to place the robotic system into a safe state; however, it is understood that the term "safe" may be interpreted differently in accordance with the robotic system design (for example, this could be interpreted as a complete shutdown for some systems, while for other systems a less harsh interpretation may be considered). In addition, certain systems may have overriding "stop" or "E-stop" actions defined as part of their system design and/or performance spec. For this capability, the WIPTs will attempt to best define an E-Stop capability and resultant action that can be best adapted given these ambiguities. Subsequent versions may attempt to provide more specific actions or progressive capabilities associated with this requirement.

Other Guidance: JAUS messages may need to be recommended.

3.1.2.10 Heartbeat (Liveness)

Description: Specifies the provision of a simple heartbeat mechanism to detect the introduction, removal or failure of communications. This is often used to provide awareness and reaction to a loss or intermittency of communications.

Limitations and Constraints: At a minimum, a high level duplex heartbeat between the robotic platform and its controller(s) is deemed to be sufficient to support the basic capability.

Other Guidance: Current JAUS capabilities are intended to map to/provide this functionality.

3.1.3 Mobility

3.1.3.1 Drive Mode

Description: Specifies a set of modes used to position the platform utilizing the integrated mobility system such that the system can be commended to and/or report its driving mode. At a minimum, the following driving modes are considered applicable:

Remote Control (RC)	Provides the ability to move/drive the platform with eyes on the robotic system
Teleoperation (Teleop)	Provides the ability to move/drive the platform through a dedicated sensor(s).
Basic Navigation (BN)	Provides the ability to move/drive the platform via a defined set of points specified by an external source.
Leader/Follower (L/F)	Provides the ability to move/drive the platform in relation to an external source (e.g., vehicle or dismounted soldier). In this mode the robotic platform may be designated as either a leader or a follower.

Limitations and Constraints: Some of the driving modes (e.g., basic navigation) may require an autonomy package integrated to the platform vehicle control system. This version is not concerned with defining those internal interfaces at this time or further subsetting capabilities into mobility payload packages. It is; however, likely that these interfaces (and potentially additional subsetting) will be defined in subsequent revisions. The degree to which mobility modes may affect, limit, or relate to the platform mode should be considered in the detailed definition of this capability. In addition, the successful transition into some driving modes may be dependent upon the availability and status of a related subsystem (for example, selection and enabling of a driving sensor – from the point of view of the robotic platform – may be required prior to successful transition to and/or execution of teleop driving, where this would not be the case for other driving modes).

Other Guidance: Current JAUS capabilities are intended to map to/provide this functionality. In some cases, additional JAUS messages may need to be recommended.

3.1.3.2 Gear

Description: Conceptually specifies the manner in which the robotic platform can be commanded to and will report its method of movement (e.g., forward, reverse, pivot)

Limitations and Constraints: The manner in which this capability is implemented will be determined by the WIPTs as systems vary with respect to the implementation of this capability. The term conceptual is used in the description as a specific drive select function may not be required (e.g., utilization of +/- values could determine direction vs. a separate mode variable). The main requirement is to consistently map the required behavior. This capability is applicable to the RC and Teleop drive modes.

Other Guidance: Current JAUS capabilities are intended to map to/provide this functionality.

3.1.3.3 Speed/Acceleration

Description: Specifies the manner in and the degree to which the robotic platform will move and report its movement as commanded/queried by an external source. This will also allow control of speed and acceleration, as defined by the speed and acceleration limits.

Limitations and Constraints: It is envisioned that for the basic platform there will be one method defined and associated with this capability. The capability to set is applicable to the RC and Teleop drive modes.

Other Guidance: Current JAUS capabilities are intended to map to/provide this functionality.

3.1.3.4 Speed/Acceleration Limits

Description: Specifies the limits associated with the movement of the robotic platform. These are intended to be reported only and not set by an external source, as these limits are inherent platform constraints and not user defined or settable.

Limitations and Constraints: There may be an association of these limits in relation to the commanded speed and acceleration. If so, the WIPTs will need to define those relationships. This capability to set is applicable to the RC and Teleop drive modes.

Other Guidance: Additional JAUS messages may need to be recommended.

3.1.3.5 Steering

Description: Specifies the manner in and the degree to which the robotic platform will turn and report its turning as commanded / queried by an external source.

Limitations and Constraints: It is envisioned that for the basic platform there will be one method defined and associated with this capability. This capability is applicable to the RC and Teleop drive modes.

Other Guidance: Current JAUS capabilities are intended to map to/provide this functionality.

3.1.3.6 Brake

Description: Conceptually specifies the manner in which the vehicle will slow or decelerate. This capability is stated to be conceptual due to the fact that braking may be defined as the absence of acceleration vs. a specific independent function in accordance with the system design.

Limitations and Constraints: Regardless of the presence or absence of a physical brake(s), this capability shall be implemented consistently. This capability is applicable to the RC and Teleop drive modes.

Other Guidance: Current JAUS capabilities are intended to map to/provide this functionality.

3.1.3.7 Drive Sensor Registration

Description: Provides the capability to identify and report a sensor as applicable to driving. Some platforms may have one (or none) driving sensor however other platforms may have multiple sensors specifically located (e.g., front, rear side) to be associated with teleoperation of the robotic platform.

Limitations and Constraints: Conceptually this capability provides an external source with information related to the availability of sensors best suited to remotely operate the platform. It may be the case that a robotic platform has only one sensor (associated with multiple tasks) or does not define a driving sensor and would need to accommodate this capability in the best manner possible. This capability is applicable to all driving modes with the exception of RC.

Other Guidance: Additional JAUS messages may need to be recommended.

3.1.3.8 Drive Sensor Selection

Description: Provides the capability to select and view sensor video associated with driving the robotic platform.

Limitations and Constraints: From the point of view of the robotic platform driving sensor(s) can be selected and enabled/disabled by an external source and there is no intent to limit the ability to send multiple or multiplexed video from several sources for display. In addition, the selection of the source is not explicitly intended to enable video transmission; however, that collective capability may be implemented within an external control system. This capability is applicable to all driving modes with the exception of RC.

Other Guidance: Additional JAUS messages may need to be recommended.

3.1.3.9 Drive Timeout

Description: Provides a capability to monitor control messages from an external source to the robotic platform at a determined frequency to ensure that a loss of commanded input along the control chain does not result in unintended consequences or safety

issues. Conceptually, this is a watchdog function to prevent stale data in the control chain from commanding the system.

Limitations and Constraints: This capability is addressed within the robotic platform (perhaps at multiple levels depending upon the control logic), but also needs to be considered external to the platform as well (for example, within a controller, multiple processes might be used to read handle data, process control input, and command vehicle movement). This capability is applicable to the RC and Teleop driving modes.

Other Guidance: Current JAUS capabilities are intended to map to/provide this functionality.

3.1.3.10 Create Waypoint/Waypoint List

Description: Provides a capability to define a waypoint and an associated list of waypoints that can be utilized for simple navigation of the robotic platform along a path.

Limitations and Constraints: This capability is intended to provide a simple navigation mechanism. The waypoint is intended to represent a geo-location and may define some simple level of tolerance with respect to signifying the capture of the waypoint itself and desired speed between path segments. Actions at waypoints, waypoint time constraints (e.g., arrival and departure), plan volatility, plan validation, multi-plan definition/selection, and waypoint corridors are deferred to subsequent versions. Plan volatility and the ability to define multiple plans are not explicitly addressed, but if addressed by the WIPTs must be done so in a manner that keeps the functionality applicable across the set of systems that provide basic waypoint navigation. This capability is applicable to the BN driving mode.

Other Guidance: Current JAUS capabilities are intended to map to/provide this functionality.

3.1.3.11 Insert/Delete Waypoint

Description: Provides the capability to insert or delete a waypoint from a waypoint plan.

Limitations and Constraints: It is presumed that waypoint insertion and deletion would only occur with respect to a non-executing plan. This capability is applicable to the BN driving mode.

Other Guidance: Current JAUS capabilities are intended to map to/provide this functionality.

3.1.3.12 Load Waypoint Plan

Description: Provides the capability to load a defined waypoint plan for processing (execution) by the robotic platform.

Limitations and Constraints: While there is no requirement to explicitly validate waypoint plans, this capability may take simple checks into account prior to signifying

the readiness to execute a specified plan. This capability is applicable to the BN driving mode.

Other Guidance: Current JAUS capabilities are intended to map to/provide this functionality. Also, for V0, the utilization of JAUS may nullify the need for an explicit "load" function. WIPTs are allowed to implement this and other waypoint functions in a "conceptual" manner. However, future planning requirements may require more separation between creation and loading with respect to waypoint (mobility) plans, as these plans may be more integrated/related to other capabilities within higher level mission plans (e.g. ISR).

3.1.3.13 Execute Waypoint Plan

Description: Provides the capability to initiate execution of a loaded waypoint plan. Once the plan is executing, there are various events that can happen that may affect the plan execution state (e.g., intervention required). These conditions need to be considered in the definition of the functionality.

Limitations and Constraints: State machine logic associated with the load, execute, pause, and resume process will need to be defined by the WIPT. In addition, the relationship of the plan execution state to the driving mode state will also need to be addressed/defined by the WIPT (e.g., selecting the teleop driving mode while the plan is currently executing). This capability is applicable to the BN driving mode.

Other Guidance: Current JAUS capabilities are intended to map to/provide this functionality.

3.1.3.14 Waypoint Plan Status

Description: Provides the capability to report the status of the plan execution state machine to an external source. Plan status will also provide an indication and distance to the current target waypoint.

Limitations and Constraints: This capability will be largely tied to the waypoint plan execution state machine model. This capability is applicable to the BN driving mode.

Other Guidance: Current JAUS capabilities are intended to map to/provide this functionality.

3.1.3.15 Suspend/Resume Waypoint Plan

Description: Provides the capability to pause and re-initiate execution of a currently loaded/executing waypoint plan.

Limitations and Constraints: Similarly to plan execution, the relationship of the plan execution state and the driving mode state will need to be addressed/defined by the WIPT. In addition, the ability to reload or re-execute a plan while in a paused state will also need to be considered. This capability is applicable to the BN driving mode.

Other Guidance: Current JAUS capabilities are intended to map to/provide this functionality.

3.1.3.16 Leader/Follower Mode

Description: Provides the ability to specify the robotic platform leader/follower mode within a leader/follower configuration. For this basic capability, the robotic platform will simply be designated as a "Leader" or a "Follower." The intent of the leader capability requirement is to provide a simple position designation to a set of external followers. The intent of the follower capability is to monitor a simple position report from a designated follower and follow the position in accordance with a defined set of attributes.

Limitations and Constraints: Similarly to basic navigation, leader/follower capability will execute in accordance with a set of defined states/state transitions. The dependencies of these states along with the platform mode and other executing mobility state machines will need to be considered. An example is specifying that the robot is to be a leader and then providing and executing a waypoint plan. This capability is applicable to the L/F driving mode.

Other Guidance: Additional JAUS messages may need to be recommended. There are multiple ways to accomplish this task, which will need to be identified and evaluated.

3.1.3.17 Formation Attributes

Description: Provides the ability to specify a set of attributes to oversee the formation during execution. In general, these attributes will be most applicable when the leader/follower mode is set to follower. Follower attributes include min/max following distance, position/offset with respect to lead vehicle, lead vehicle designation, and timeout behaviors. Leader attributes include broadcast/multicast group, position update frequency, and timeout behaviors.

Limitations and Constraints: Specific formation algorithms and multi-vehicle formations are not intended to be explicitly addressed by this capability. These formations may be addressed in future revisions or at a time when such behaviors become standardized within the community. This capability is applicable to the L/F driving mode.

Other Guidance: Additional JAUS messages may need to be recommended. There are multiple ways to accomplish this task, which will need to be identified and evaluated.

3.1.3.18 Execute Formation

Description: Provides the capability to initiate execution of configured leader/follower formation. Once the formation is executing, there are various events that can happen that may affect the plan execution state (e.g., loss of communications). These conditions need to be considered in the definition of the functionality.

Limitations and Constraints: State machine logic associated with the leader/follower execution will need to be defined by the WIPT. In addition, the relationship of the leader/follower execution state to the driving mode state will also need to be addressed/defined by the WIPT (e.g., selecting the teleop driving mode while a formation is currently executing). This capability is applicable to the L/F driving mode.

Other Guidance: Additional JAUS messages may need to be recommended.

3.1.3.19 Following Status

Description: Provides the capability to report the status of the leader/follower execution state to an external source. Although this will be defined by the WIPTs, this may include a confirmation that the follower is the correct range.

Limitations and Constraints: This capability will be largely tied to the leader/follower execution state machine model. This capability is applicable to the L/F driving mode.

Other Guidance: Additional JAUS messages may need to be recommended.

3.1.3.20 Suspend/Resume Waypoint Leader/Follower

Description: Provides the capability to pause and re-initiate execution of a defined leader/follower mode of operation.

Limitations and Constraints: Similarly to leader/follower execution, the relationship of the leader/follower execution state and the driving mode state will need to be addressed/defined by the WIPT. This capability is applicable to the L/F driving mode.

Other Guidance: Current JAUS capabilities are intended to map to/provide this functionality.

3.2 Payload

The payload section is currently divided into 3 subsections. The sensor section is used to describe devices that sense conditions, both on and off the platform. The emitter section is used to describe devices that emit or release material or energy into the platform surroundings. And finally, the actuator section described devices used to physical manipulate portions of the platform, other sensors, or the surroundings. In some cases, a payload may not be clearly placed into one of these groupings. When this occurs, the primary function of the payload will be considered, and will be identified by the RS JPO. (Example: While a laser range finder does emit electro-magnetic energy, the primary function is to sense distance.)

3.2.1 Sensor

3.2.1.1 Drive Vision

Description: Drive vision describes motion imagery necessary to drive a robotic platform in teleop mode. This provides the capability to interface drive vision payloads onto robotic systems.

Limitations and Constraints: This should include on/off, zoom, video image format, any necessary metadata required, and anything that the WIPT identifies as necessary. For V0, only simple video is required. Later versions can include frame rate adjustments, image resolution, and other settings.

Other Guidance: Additional JAUS messages may need to be recommended. Motion imagery standards should be utilized. This may be related to motion imagery.

3.2.1.2 Motion Imagery

Description: Motion imagery describes any video that is not specifically used to drive the system, although it could be used to do so. This provides the capability to interface motion imagery payload to robotic systems.

Limitations and Constraints: This could include, on/off, zoom, focus, gain, video image formats, and anything that the WIPTs deem necessary. For V0 only simple 2-D imagery is needed.

Other Guidance: Additional JAUS messages may need to be recommended. This may be related to drive sensors.

3.2.1.3 Still Imagery

Description: The robot may need to take still imagery at times. This provides the capability to interface still imagery payload to robotic systems.

Limitations and Constraints: This feature can be defined by the WIPTs, but may include capture commands, zoom, and image format among other parameters.

Other Guidance: Additional JAUS messages may need to be recommended.

3.2.1.4 CBRN

Description: Provides the capability to interface Chemical, Biological, Radiology and Nuclear (CBRN) detection sensors to robotic systems.

Limitations and Constraints: The V0 plan should include on/off, sensitivity levels, specificity of chemical, false alarm control, and anything the WIPT determines is necessary. This capability will need to expand in the future, as additional requirements are identified.

Other Guidance: Joint Program Executive Office for Chemical Biological Defense (JPEO-CBD) is developing a standard for sensor physical, electrical interfaces, power requirements, component interconnections, power and external connectors for CBRN sensors. Additional JAUS messages may need to be recommended.

3.2.1.5 Chemical Explosive Detection

Description: Provides the capability to interface chemical explosive detection sensor to robotic systems.

Limitations and Constraints: This may include on/off, sensitivity levels, specificity of chemical, false alarm control, and anything else the WIPT identifies that is required.

Other Guidance: Additional JAUS messages may need to be recommended.

3.2.1.6 Microphone

Description: Provides the capability to interface microphone sensors to robotic systems. This will allow the operator to collect audio from the area in which the robot is located.

Limitations and Constraints: The V0 plan should include on/off capability and audio format. The V0 plan is not intended to include the ability to perform gunfire detection, or sonar-type mapping.

Other Guidance: Additional JAUS messages may need to be recommended.

3.2.1.7 Range Finder

Description: Provides the capability to interface electronic range finder payloads to robotic systems. Laser range finders (LRF) (aka Light Detection and Ranging (LIDAR) or Laser Detection and Ranging (LADAR) sensors) are a combination emitter and sensor but their primary function is to “sense” distance to objects. Some LRF are used in target acquisition to determine distance to targets, but there are also scanning laser range finders that are used in robotics to develop three dimensional map of surroundings for autonomous path following and obstacle detection. Further, this capability can also be deployed in detecting Nuclear Biological and Chemical (NBC) particle clouds.

Limitations and Constraints: This should include on/off capability, type of range finder, distance to target, and data format. For V0, LIDAR units are not included. V0 will only require simple range finding.

Other Guidance: Additional JAUS messages may need to be recommended.

3.2.1.8 Thermal

Description: Provides the capability to interface thermal sensors to robotic systems. Thermal sensors are used for the sensing of heat changes.

Limitations and Constraints: V0 will include on/off capability, type of thermal sensor and data format. For V0, the thermal sensors will be still and motion imagery based, and not individual thermal sensors such as thermistors or thermocouples. Based on the recommendations of the WIPT, this feature may match up with still and motion imagery.

Other Guidance: Additional JAUS messages may need to be recommended.

3.2.2 Emitter

3.2.2.1 Lights

Description: Provides the capability to interface lights to robotic systems.

Limitations and Constraints: This will include on/off capability. The intent is to control simple lights to enhance visual capabilities. The intent is not to control advanced lighting systems, dazzlers, laser designators, and the like for V0. WIPT members will determine other capabilities that need to be added.

Other Guidance: Additional JAUS messages may need to be recommended.

3.2.2.2 Speaker

Description: Provides the capability to interface speakers to robotic systems.

Limitations and Constraints: V0 should include on/off capability, audio format, and volume, as well as other controls required by the WIPT. V0 is not intended to provide acoustic weapon capabilities, or other advanced capabilities. The audio format and frequency range may need to be determined.

Other Guidance: Additional JAUS messages may need to be recommended.

3.2.3 Actuator

Actuators can be considered very similar in that they are a collection of various components with various degrees of freedom. An actuator could be as simple as controlling translations and rotations. However, in some cases, there may be important features the user or robot may need to be aware of. As a result, specific actuators are described and included.

3.2.3.1 Actuators

Description: Provides the capability to interface actuators to robotic systems.

Limitations and Constraints: The V0 profile should include the type of actuator (linear or rotary), on/off, position, speed, and other parameters required by the WIPT. As there are many different possible embodiments of an actuator, only a simple set should be considered.

Other Guidance: Additional JAUS messages may need to be recommended.

3.2.3.2 Basic Arm

Description: Provides the capability to interface a basic arm manipulator on robotic systems. An arm could include a payload, which is positioned by the arm.

Limitations and Constraints: The V0 profile should include degrees of movement, type of joint movement, on/off, position, speed, and other features recommended by the WIPTs.

Other Guidance: ISO 8373 should be considered. Additional JAUS messages may need to be recommended.

3.2.3.3 Telescoping (Mast)

Description: Provides the capability to interface telescoping mast to robotic systems. The mast would commonly include a payload that is raised/lowered or extended/retracted.

Limitations and Constraints: V0 should include position information, on/off, speed, as well as any other requirements as defined by the WIPT members.

Other Guidance: ISO 8373 should be considered. Additional JAUS messages may need to be recommended.

3.2.3.4 Pan/Tilt

Description: Provides the capability to interface pan/tilt payload to robotic systems. The pan/tilt mechanism can be used to change the direction of another payload. The classic example is a camera that can look left/right/up/down by moving the pan and tilt feature.

Limitations and Constraints: V0 should include position/rotation information, on/off, speed, as well as other features required by the WIPTs.

Other Guidance: ISO 8373 should be considered. Additional JAUS messages may need to be recommended.

3.2.3.5 End Effectors

Description: Provides the capability to interface end effectors payload to robotic systems. The end effectors are the end-of-arm tooling on a robot. As other payloads can be attached to the end of an arm, such as a sensor or emitter, the end effector payload is defined as an actuator based system, like a gripper or cutter.

Limitations and Constraints: V0 should include position/rotation information, on/off, speed, as well as other features required by the WIPTs.

Other Guidance: ISO 8373 should be considered. Additional JAUS messages may need to be recommended.

3.3 Communications

The communication IOP capabilities are focused on the interoperability of the communications system as interfaced to the robotic platform and to the controller system. For V0, the interface between radios (e.g., protocols, waveforms) as well as the interoperability of heterogeneous radio systems are not specifically addressed. The main intent is to focus the communications profile to support the set of currently fielded systems (platforms and controllers) and to consider the radio as a black box plug-in to both the robotic platform and the controller systems. As the Army community defines requirements for large scale network integration of robotic platforms and controllers, the communications profile capabilities will evolve. The communications WIPT may consider the establishment of working groups in this area as well as in areas dealing with mesh technologies, encryption, quality of service, etc., to contemplate paths forward as well as standardization and interoperability approaches related to these topics in preparation for these requirements.

3.3.1.1 Radio Link

Description: Provides the ability to establish a point to point communications link between one controller and one robotic platform (closed network).

Limitations and Constraints: This capability shall take into consideration the setting of radio configuration values commensurate with currently fielded systems (e.g., frequency channel).

Other Guidance: It is desirable for the identified radio link parameters/configuration settings to be settable from the controller system.

3.3.1.2 Radio Subsystem Interface

Description: Provides for interoperability with respect to the radio subsystem interface to the robotic platform and the radio subsystem interface to the controller. This interface shall consider the manner in which the radio is interfaced with respect to data bus/network and data packets to include both control data/status as well as video.

Limitations and Constraints: The intent of this capability is to accommodate currently fielded systems with respect to the receipt and transmission of data and video to/from the robotic system from a controller. This capability will need to consider software and hardware related to the networking and packetization of this data (e.g., Ethernet, IP).

Other Guidance: N/A

3.3.1.3 Radio Frequency Interference (RFI) Mitigation

Description: Provides the ability to enable the operation of multiple UGV systems simultaneously in the same area with minimal performance degradation. This includes the identification (to include control and status techniques) of parameters/configuration settings that can be queried, accessed, and set to enable maximized performance of UGVs operating in the same vicinity (examples of parameters may include frequency settings, transmit power, etc).

Limitations and Constraints: The intent of this capability is to maximize the inter-operation of multiple one to one controller/robot systems within the same operational area. This feature is not intended to be an automatic frequency adjustment.

Other Guidance: It is desirable for the identified parameters/configuration settings to be settable from the controller system.

3.3.1.4 Radio Status (Health)

Description: Provides the ability to query/report the radio status to the controller or robotic platform.

Limitations and Constraints: This capability shall take into consideration the availability of link/health data currently available in fielded systems with the minimum goal of establishing the health of the radio and the network/link status. Other potential attributes include: SNR, Center Frequency, Channel Frequency Response, Latency, Point of Modulation Bandwidth, Packet Error Rate (%), Data Rate (Mbps), Modulation Scheme, RF Transmit Power (dBm), Received Signal Power (dBm), Error Vector Magnitude (EVM), Mode of Operation (Point-to-Point or Multipoint).

3.3.1.5 Wireless Security

Description: Provides the ability to establish secure, encrypted wireless communications links.

Limitations and Constraints: For the purposes of V0, this shall be limited to querying for the available encryption schema on a given radio, and turning encryption schema on or off. Future versions of the IOP are anticipated to expand the wireless security capabilities.

Other Guidance: N/A

3.4 Control

The control IOP capabilities are focused on interoperability as it relates to a control device, specifically in the areas of commonality, operator interfacing, and external system interfacing to exchange information to/from the robotic platform (e.g., maps, sensor/image data, Command and Control (C2) and situational awareness data). Commonality in this sense does not necessarily mean only the standardization of the user interface, but instead is focused towards usability, common presentation of information, and common interaction techniques across a variety of input and output devices.

Major requirements sections within the Control IOP include Software, Human Computer Interface (HCI), C2, and Mission Planning. The following sections address the requirements focus for these areas with respect to V0 capabilities.

3.4.1 Software

These requirements are related to standardization of operating system, operating system isolation and graphics software to support application interoperability. In addition, the introduction of vendor plug-in software and safety critical applications would require the need to define interoperability requirements in this area. For V0, these requirements will not be specifically addressed, however working groups could be established to discuss needs and future standardization in these areas. It is also likely that the Army's Common Operating Environment (COE) initiative will explicitly define/mandate standards and application software related to these requirements and as such, will defer detailed analysis in this area until V1 or later.

3.4.2 HCI

These requirements are related to the standardization of the human computer interface employed within the controller systems. It is understood that controllers will be adapted to various input/output device configurations and as such, these requirements will not be focused on a common interface but will be more focused on common techniques to be adapted across interfaces applying to both the output of information to a soldier and the input controls required to implement the soldier's intent to a robotic platform.

3.4.2.1 Battery Status

Description: Provides the status of the battery(ies) or other power source utilized to power the controller. The intent is to provide a current charge level of the battery or status of the power system.

Limitations and Constraints: The intent is to provide just the charge level of the battery, allowing the user to make informed decisions about mission capability. In subsequent versions, additional information may be added (e.g., battery chemistry, loads, temperature, critical levels). The WIPTs may add additional information as deemed important for basic functionality, but advanced functions should not be pursued at this time.

Other Guidance: N/A

3.4.2.2 Radio Setup and Communications Link Monitoring

Description: Provides the ability to select a radio configuration and establish and monitor an RF connection to a robotic platform.

Limitations and Constraints: This capability is meant to map closely to capabilities currently provided in fielded systems as well as capabilities developed/identified within the communications portion of the IOP.

Other Guidance: N/A

3.4.2.3 Robotic Asset Selection, Login, and Controls

Description: Provides the ability to select and login to a robotic asset. This includes the ability to command startup, shutdown, and operational usage of the robotic asset and to the degree specified within other areas of the profile determine available capabilities/configuration of the robotic platform.

Limitations and Constraints: This capability should be limited by the degree to which other capabilities are defined within the overarching and payload profiles with respect to discovery and configuration of the robotic platform and could range from a simple selection/visualization of the asset under control to a broader capability that presents the robotic configuration to the controller.

Other Guidance: N/A

3.4.2.4 Common Icons and Graphics

Description: Provides the ability to define common graphics and icons to be utilized in the presentation of robotic information and status to the operator.

Limitations and Constraints: In general, this capability is aimed at determining graphics and icon commonality related to the capabilities available in currently fielded systems and capabilities defined/implemented for V0. Icons and graphics could include things such as robot position/articulation, arm articulation, speed, communications link/link status, battery status, etc.

Other Guidance: N/A

3.4.2.5 Basic Status

Description: Provides the ability to define basic status information along with guidelines for presentation to be displayed/communicated to the operator. This could be status related to current robotic platform states/modes, date/time group, robotic asset position/location, battery status (platform and OCU), fuel, RPM, temperature, etc.

Limitations and Constraints: This capability will be limited by the set of information defined within other portions of the profile for V0.

Other Guidance: The guidelines are meant to provide some basic rules/rationale for when/how the information should be displayed. For example, vehicle attitude data may be specified to be always available during teleoperation and selectable at other times (e.g., when observing or when in autonomous mode).

3.4.2.6 Warnings Cautions and Alerts

Description: Provides the ability to receive and display warnings, cautions, and alerts (WCAs) to the operator in a predictable and prioritized manner. WCAs may be generated by the robotic platform or internally generated on the controller system. Examples could include low battery, over temperature conditions, component failure, or tip hazard.

Limitations and Constraints: This capability is intended to provide some common means to display and dispatch WCAs and could include the definition of one or more display mechanisms that could include operator cueing (e.g., audible or graphic). The resultant implementation could be specific (e.g., the definition of a widget to be incorporated into a WMI design) or more abstract (e.g., a structure and rule set for handling and presenting WCAs to the operator.

Other Guidance: N/A

3.4.2.7 State and Mode Selection

Description: Provides the ability to select and indicate various states and modes of operation for the robotic platform in accordance with its capabilities. This could include mobility modes (teleoperation, autonomous) as well as selection of manipulator control modes.

Limitations and Constraints: This capability will be limited by capabilities specified within other parts of the profile and is intended to map to current capabilities implemented within fielded systems as well as the overarching and payload capabilities specified within V0.

Other Guidance: N/A

3.4.2.8 Input Device Mapping (Mobility and Manipulator Control)

Description: Provides the ability to define a set of common controls/control mappings for mobility (teleoperation) and manipulator (arm) control.

Limitations and Constraints: This capability is intended to provide common mappings to various input devices (e.g., game controllers, joystick, etc) to control mobility and manipulator payloads for the robotic platform. This is intended to be a rule set to map to devices currently integrated with fielded controllers. At this point in time, this is not intended to address advanced control capabilities such as speech, gesture recognition, etc.

Other Guidance: N/A

3.4.2.9 Video Window (Viewing and Controls)

Description: Provides the ability to select and view video from a robotic platform to include the selection of the video source and the provision/implementation of video controls in accordance with the sensor (e.g., FOV, focus, zoom, TV/IR, etc)...

Limitations and Constraints: This capability is intended to map to video capabilities of currently fielded systems and will be limited by the capabilities defined within the V0 payload profile.

Other Guidance: N/A

3.4.2.10 Image/Video Archive and Browsing

Description: Provides the ability to store and retrieve images and video taken from a robotic sensor.

Limitations and Constraints: In general, this capability provides a standardized mechanism to archive and retrieve image and video data captured from a sensor on a robotic platform. Metadata requirements such as the platform, time of day, location, orientation, sensor attributes, etc may be required to be stored with the imagery and should be taken into consideration when defining this capability,

Other Guidance: N/A

3.4.3 Command and Control (C2)

These requirements are related to the interfacing of a controller to battlefield command and control systems to receive and transmit command and control and situational awareness data. For V0, these requirements will not be specifically addressed, however working groups could be established to discuss needs and future standardization in these areas. It is likely that ongoing work in PEO-I and the Army's Common Controller program could lead to the establishment of future requirements in this area.

3.4.4 Mission Planning

These requirements are related to interoperability between controllers and mission planning systems to exchange unmanned asset plans which can be sent to/received from robotic platforms. V0 defines requirements for simple autonomy (mobility/waypoint plans) related to single robotic assets.

3.4.4.1 Mission Plan Metadata and Graphics

Description: Provides the ability to specify a set of simple mission plan features (e.g., waypoints, corridors) and plan parameters (e.g., speed) in support of the waypoint planning and leader/follower capabilities specified for V0.

Limitations and Constraints: For V0, this capability is limited to plan structures and plan graphics specified for internal use. This capability should consider current doctrine and symbology related to mission planning, and while this capability should be specified to map to external planner systems, there is not a direct intent to adopt or explicitly define an interface to a current planning software application or product. In addition, it is likely that metadata formats/structures defined in this version will be adapted/expanded for future versions.

Other Guidance: Mil-Std 2525 should be utilized for the specification of common symbology.